Thermal Materials Workshop 2001

Application of Foam Metal Technology to Aircraft Systems- Direction and Status

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NORTHROP GRUMMAN

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY) 30-05-2001	2. REPORT TYPE Workshop Presentations	3. DATES COVERED (FROM - TO) 30-05-2001 to 01-06-2001

4. TITLE AND SUBTITLE Application of Foam Metal Technology to Aircraft Systems- Direction and Status Unclassified	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Klein, John ; Whiteside, Jim ;	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME AND ADDRESS Northrop Grumman xxxxx xxxxx, xxxxxxx	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS Office of Naval Research International Field Office Office of Naval Research Washington, DCxxxxx	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES
See Also ADM001348, Thermal Materials Workshop 2001, held in Cambridge, UK on May 30-June 1, 2001. Additional papers can be downloaded from: http://www-mech.eng.cam.ac.uk/onr/

14. ABSTRACT
? Outgrowth of DARPA Ultra-Lightweight Metallic Structures Program ? GASAR Component Design, Production, Test, and Cost-benefit Study (our introduction to this community) ? MURI (foams and periodic structures) ? Present Project ? Structurally Integrated Thermal Management of Airborne Early Warning & Electronic Warfare Systems ? Technology Transition ? DARPA Synthetic Multi-Functional Materials ? Rules and Tools, Relevant Database ? E-2C, Other Applications

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 23	19. NAME OF RESPONSIBLE PERSON Fenster, Lynn lfenster@dtic.mil
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007

Program Participants

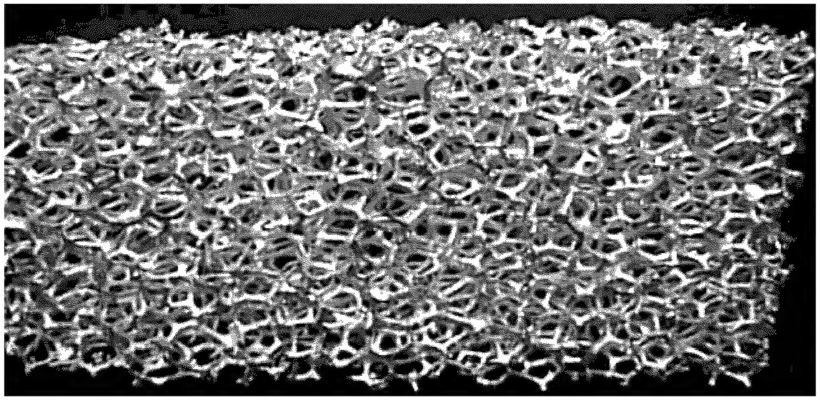
- Northrop-Grumman Corporation
  - Technology Development, AEW&EW systems business area
  - Logicon
- ONR / DARPA
- Ozer Engineering
- ERG

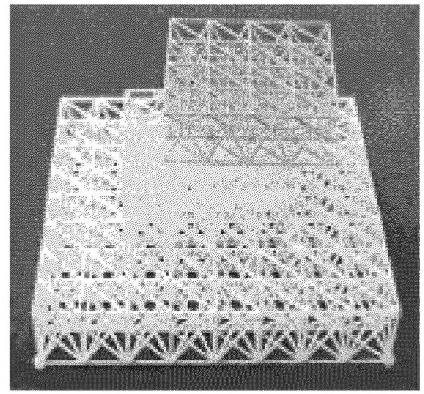
Introduction

- Outgrowth of DARPA Ultra-Lightweight Metallic Structures Program
  - GASAR Component Design, Production, Test, and Cost-benefit Study (our introduction to this community)
  - MURI (foams and periodic structures)
- Present Project
  - Structurally Integrated Thermal Management of Airborne Early Warning & Electronic Warfare Systems
  - Technology Transition
  - DARPA Synthetic Multi-Functional Materials
  - Rules and Tools, Relevant Database
  - E-2C, Other Applications

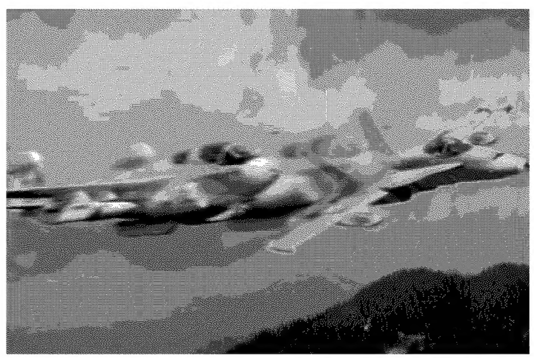
Technical Areas

- Generic Technologies - Thermal and Structural Behavior of Metal Foams and Lattice Structures





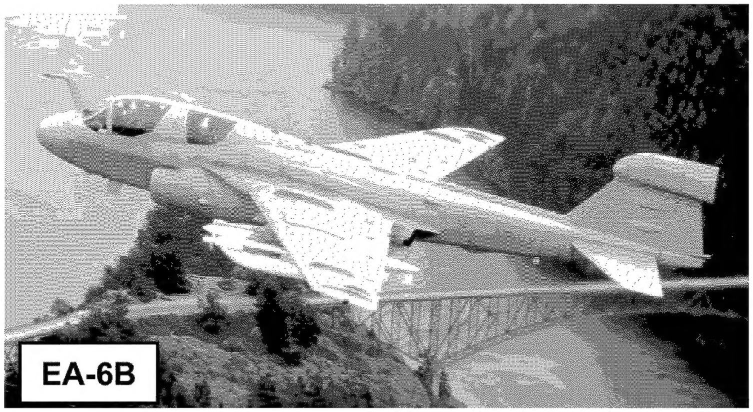
- Specific Applications - Thermal Management for Airborne Early Warning & Electronic Warfare Systems

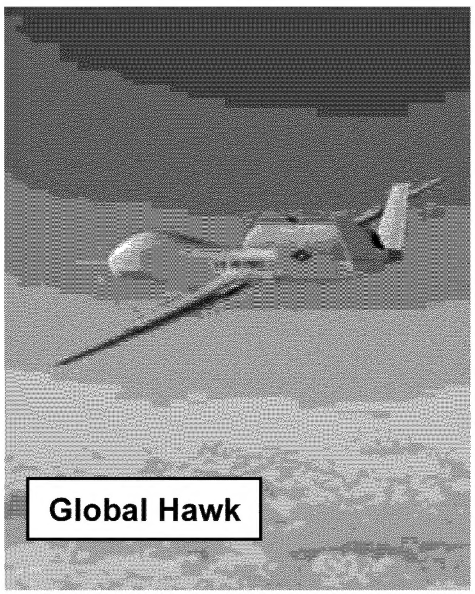


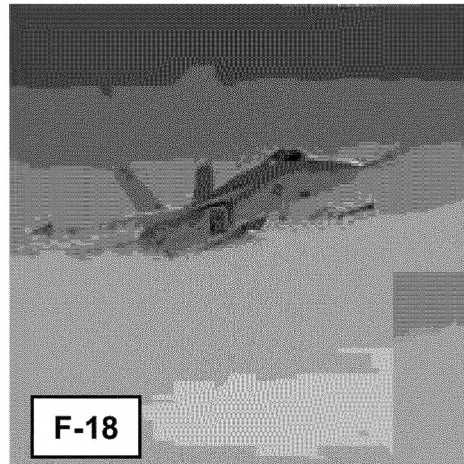
Applications

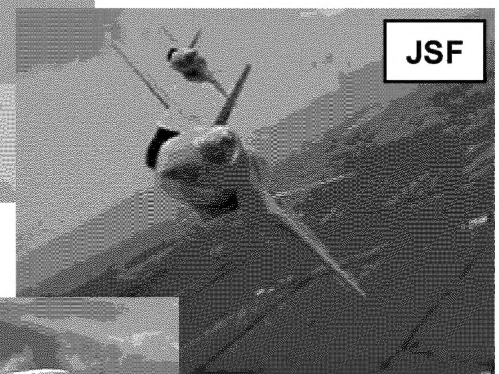
- E-2C Heat Exchanger Cores
- E-2C Avionics Racks
- EA-6B, F/A-18E/F, F/A-18G, JSF
- Unmanned Air Vehicles
- Commercial

High Efficiency Porous Metal Heat Exchangers









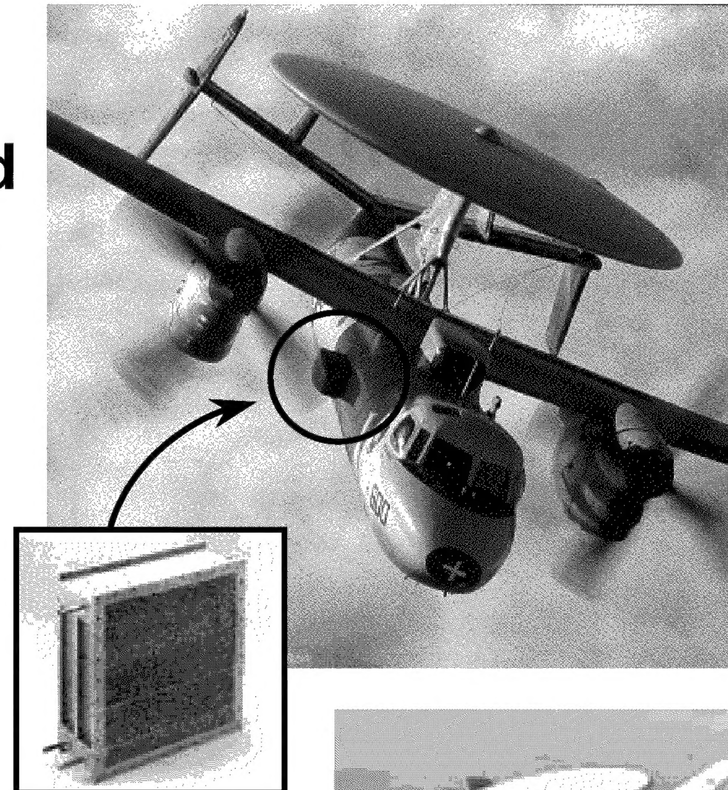
Project Tasks

- 1a. E-2C LCS Heat Exchanger Element - Design, Fabrication and Test
- 2a. Heat Exchanger Elements for E-2C Avionics Racks – Concepts

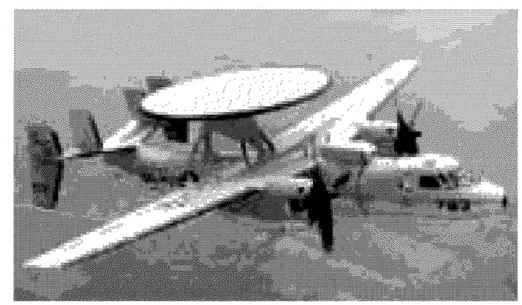
E-2C Air/Liquid Heat Exchanger

- Conventional Redesign of Air/Liquid Heat Exchanger to Accommodate Increased Load Plus Growth Large and Heavy
- Porous Metal Heat Exchanger Offers the Potential to be:
    - Lighter
    - Smaller
    - Less Expensive

  Than Conventional Redesign



Foam Metal
Heat Exchanger



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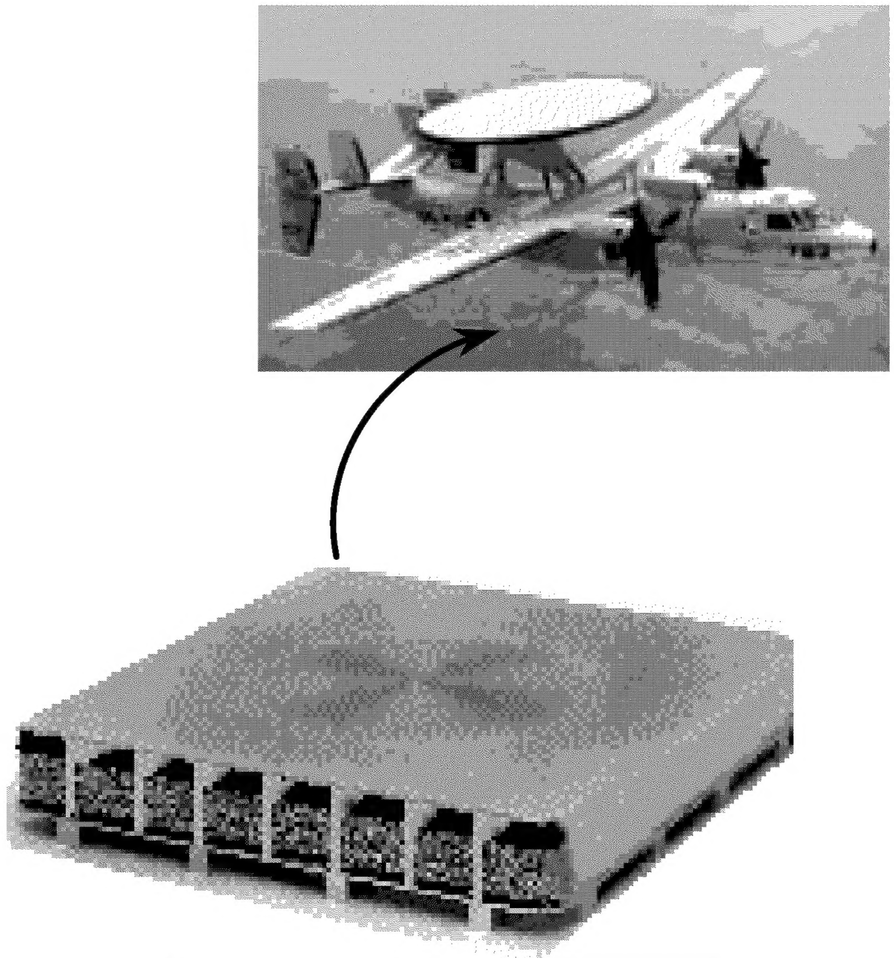
Integrated Systems
Sector

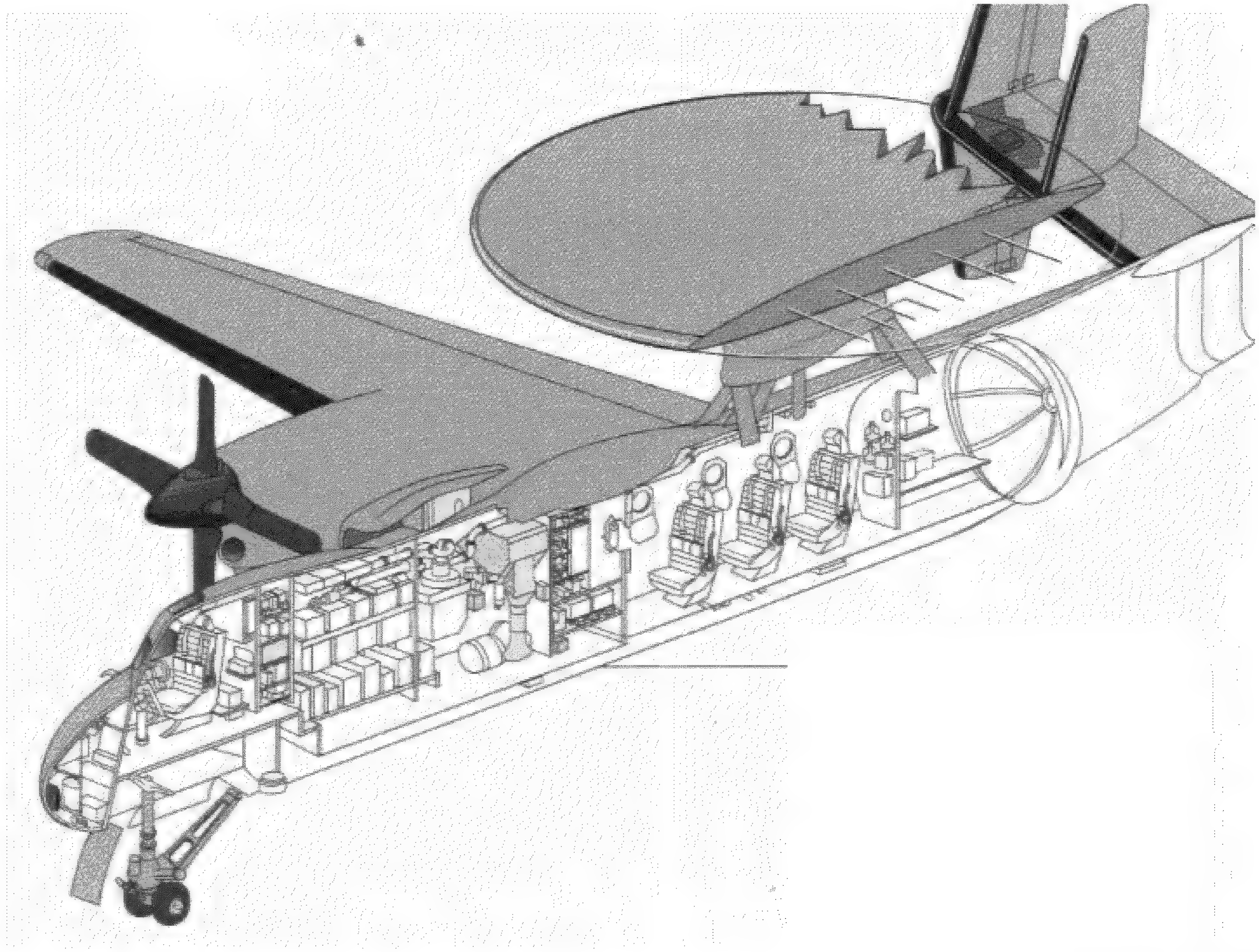
E-2C Integrated Avionics Rack



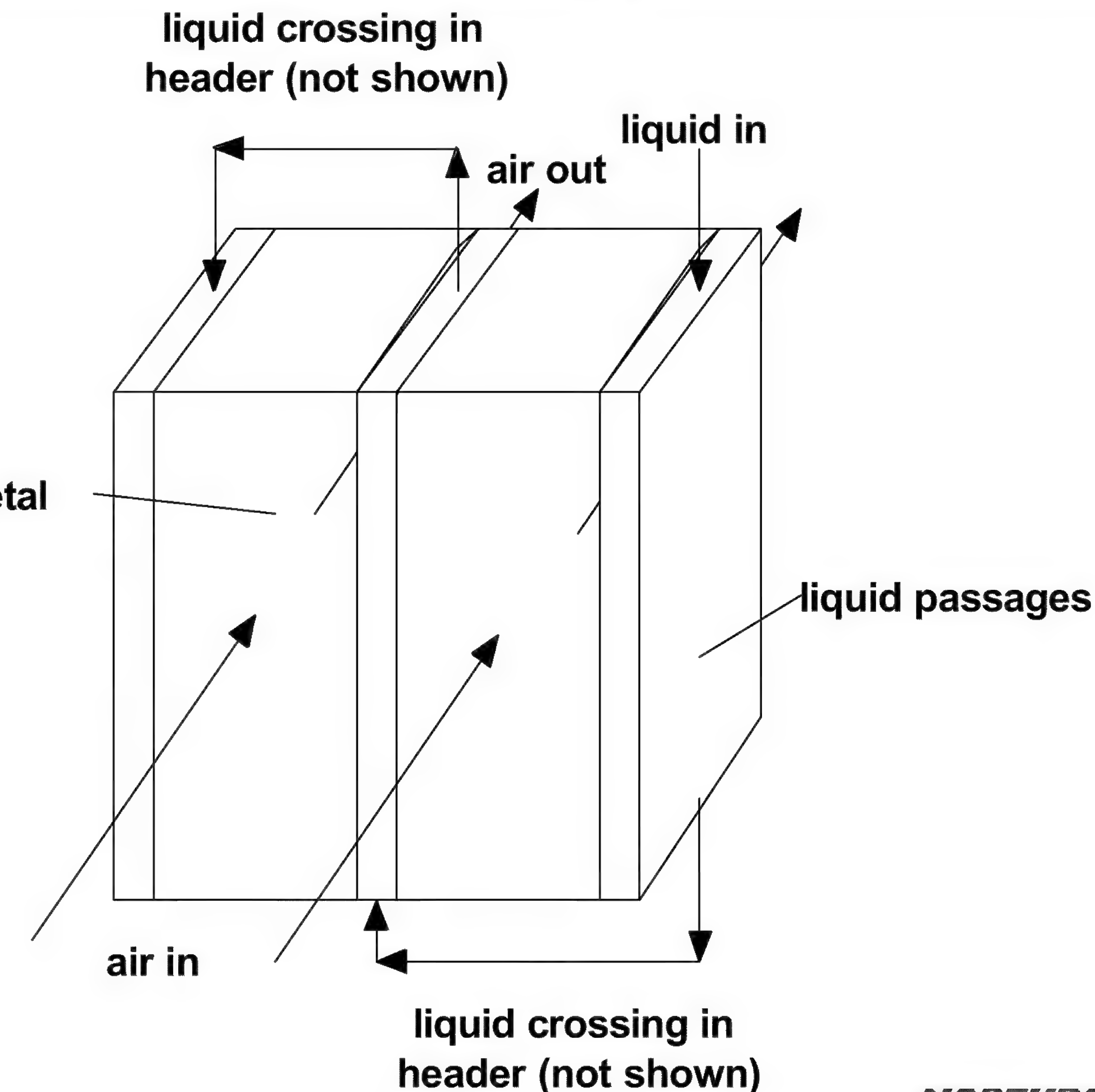
Integrated Avionics Rack

- New Avionics Suite and Redesign of Racks and Cards and Allow for an Integrated Approach to System Cooling
- Opportunity to Address Thermal Management by Incorporating Integrated Cooling Capability
- Integrated Racks Offer Weight, Performance, Size Advantages

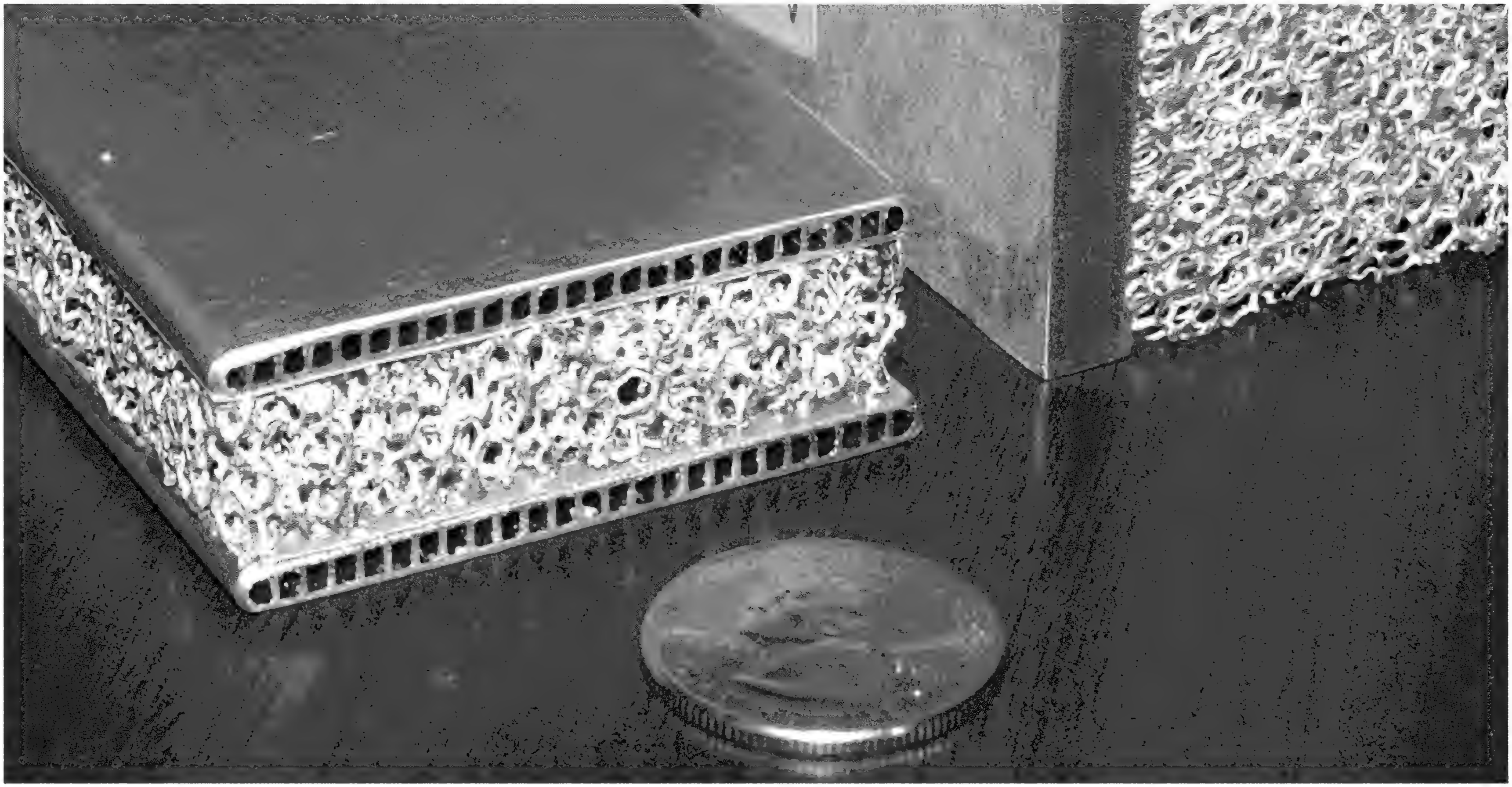
E-2C Interior



Foam Metal Heat Exchanger Basic Concept



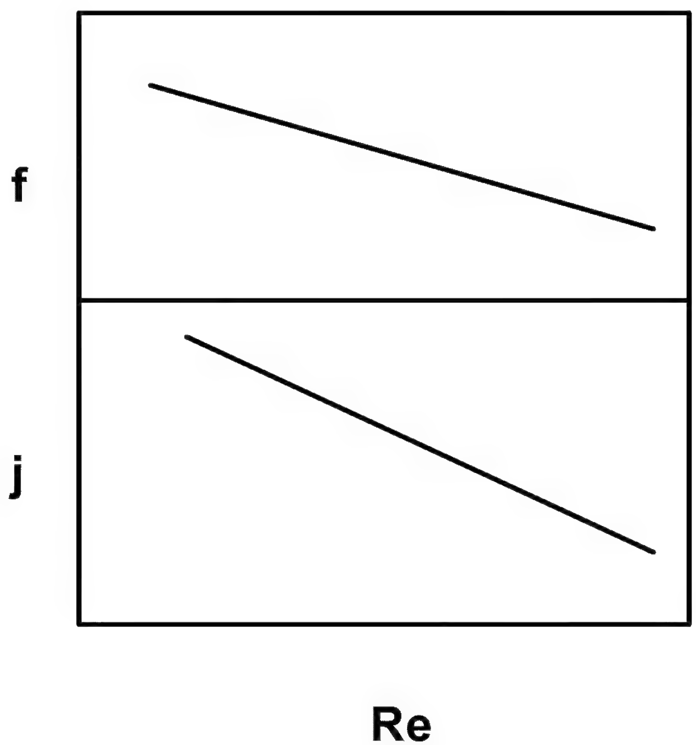
Manufacturing Demo Samples (ERG)



Data requirements

- Heat transfer and pressure drop vs Reynolds Number
  - Compressed Foams
  - Heff, ie $\eta \, h_{true} \, A_{es}$
  - $\Delta P/L$
  - Present In preferred Kays & London (K&L) Heat Transfer Data Format
    - Ref: Compact Heat Exchangers, Kays & London

Kays & London   Data Presentation



Friction factor

$$f = \frac{\Delta p}{4\left(\frac{L}{D_h}\right)\left(\frac{\rho V^2}{2}\right)}$$

Colburn j factor

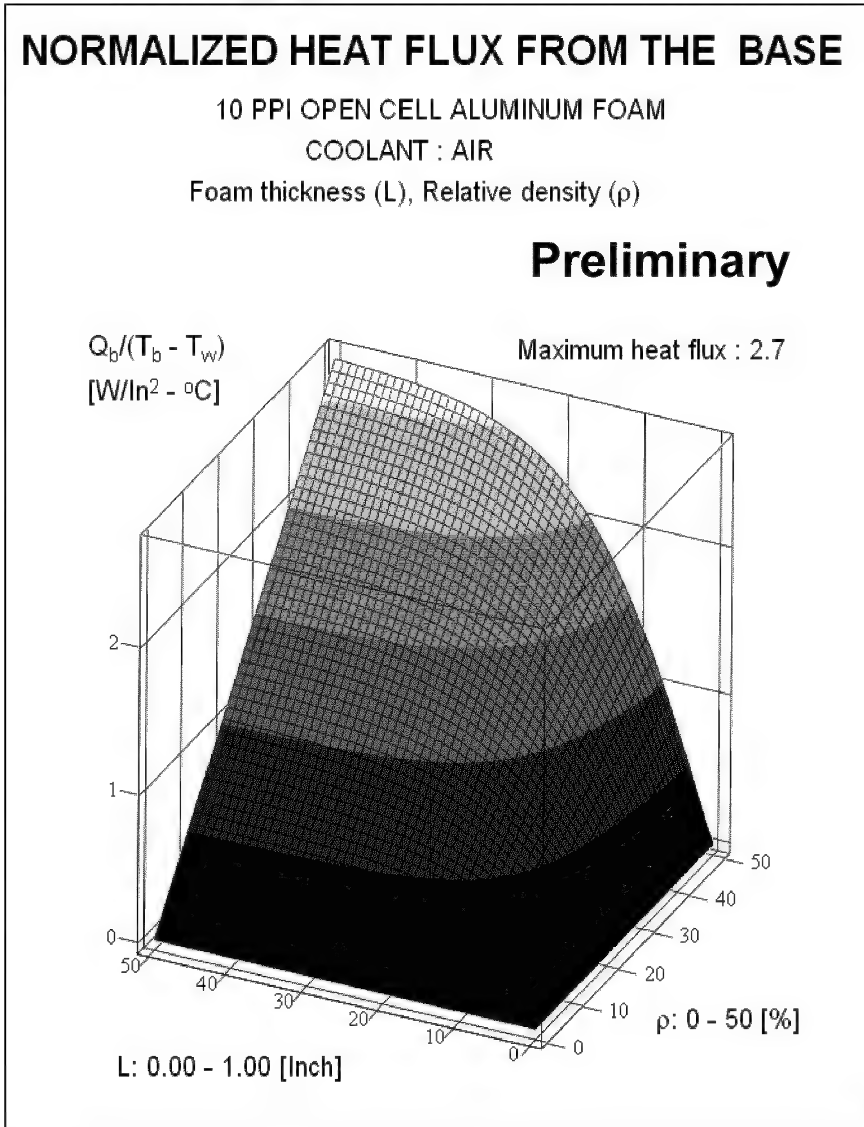
$$j = \frac{h}{\rho c_p V} P_r^{2/3}$$

$$= St * Pr^{2/3}$$

Definition of Terms

- Flow velocity
  - V= mass flow rate /(ρ A_{min}) , where A_{min} is the minimum flow area.
  - matrices $G = \rho V = W/(pA_{fr})$
- Hydraulic diameter:
- D_h = 4 x (minimum flow area) / (total heat transfer area)
- L = flow length of heat exchanger
- $R_e = \rho\ V\ D_h\ /\ \mu$

Projected Heff 10 ppi foam-sea level

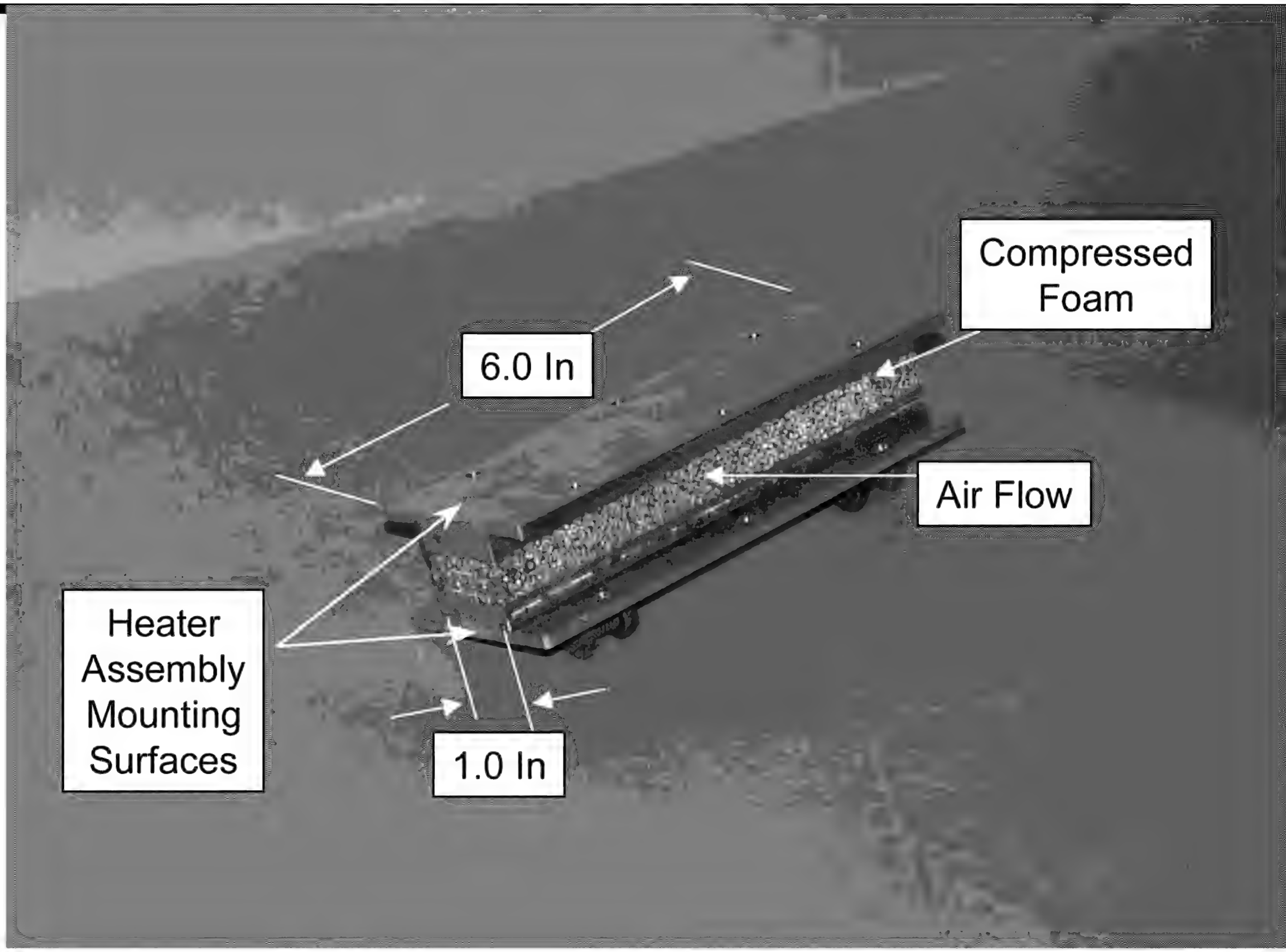


Heat Exchanger Design Methodology

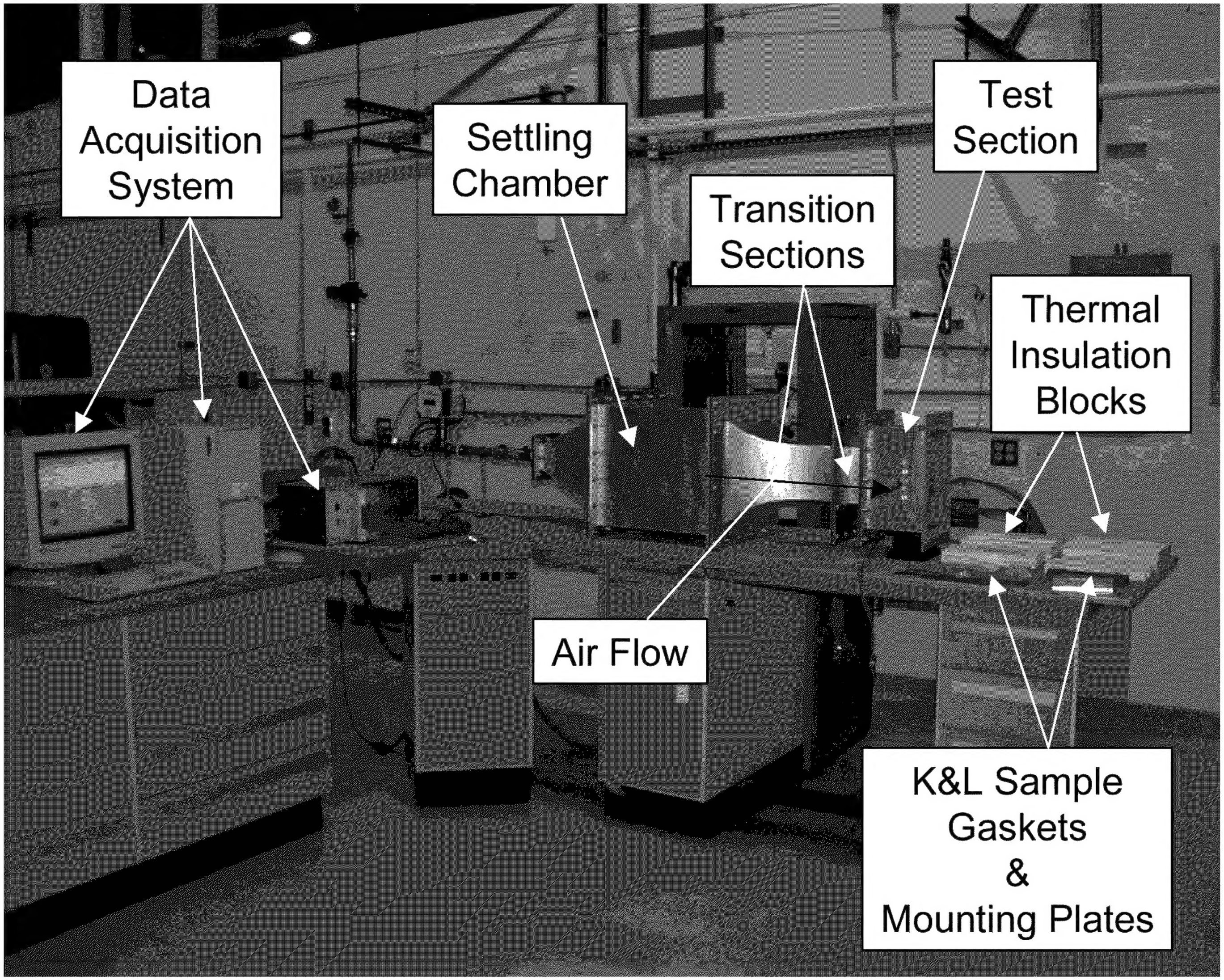
- Kays & London type measured data for extended surface
  - pressure drop vs. Re
  - heat transfer vs. Re
- Calculate h using K&L type data
- Apply <u>same</u> h to both extended surface and wall
- Calculate extended surface temperature effectiveness based on h, mat'l and geometry
- Calculate effective total heat exchange area

K&L Test Apparatus

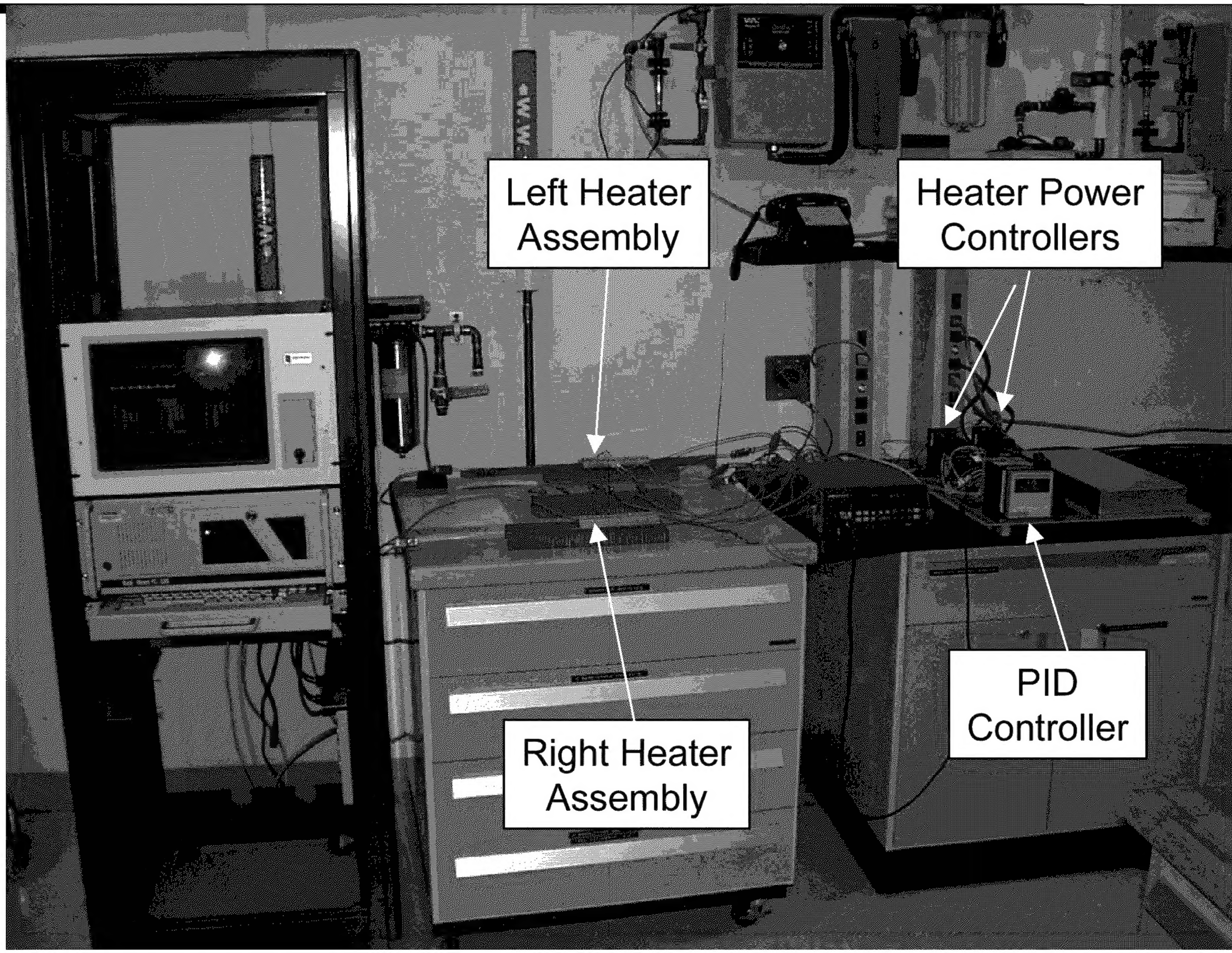
NGC KAYS & LONDON TEST SAMPLE



KAYS & LONDON TEST APPARATUS



K&L HEATER POWER PID CONTROL TEST



Summary - Technical Status / Direction

- E-2C LCS heat exchanger
  - Completed
    - LCS HX conceptual design
    - LCS HX initial sizing
    - K&L test apparatus design, fabrication, checkout
    - data acquisition system
    - temperature controller testing
    - air flow supply checkout
    - Instrument calibration
    - NGC K&L testing start 1-2 weeks
    - Foam metal HX sub element fabrication demo
    - Design system integration methodology

Summary - Technical Status / Direction (cont.)

- E-2C LCS work in progress
  - K&L sample testing
  - HX element fabrication demonstration
  - HX element thermal performance demonstration
  - Design system integration method verification
- E2C Integrated avionics racks
  - preliminary concepts
- Structurally integrated heat exchangers
  - preliminary concepts
- Additional specific aircraft applications